Minnesota Simulations

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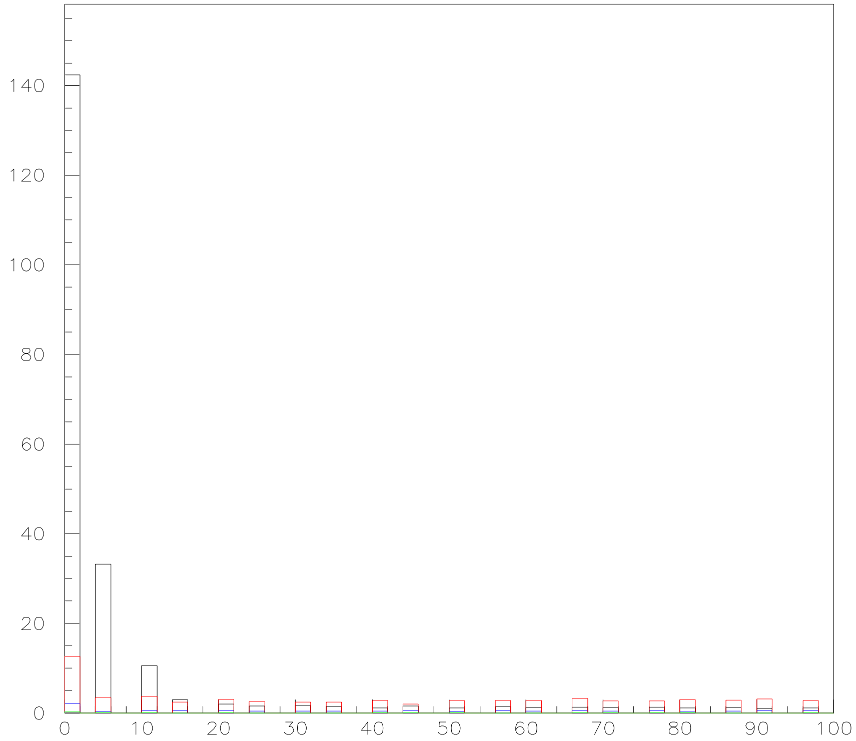
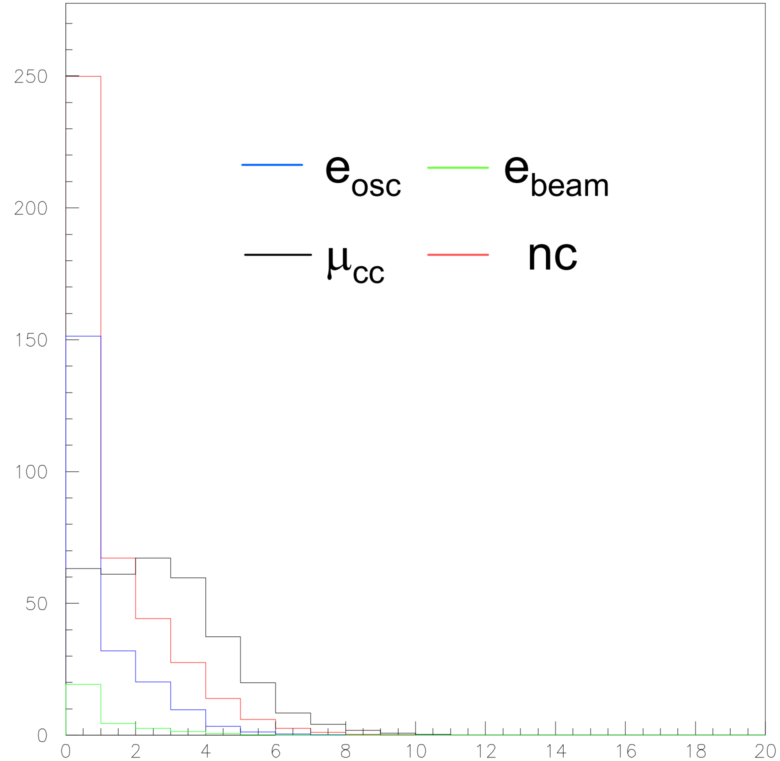
- Improvements to the Minnesota analysis
- Comparison with the Stanford analysis
- Optimisation of the cell size
- Optimisation of the off-axis position in the TA detector
- 8 GeV beam

μ decays

- μ decays are detectable through late hits near the end of tracks.
  - Look for hits later than 300ns after the first hits in the event



z distance from track end (cm)

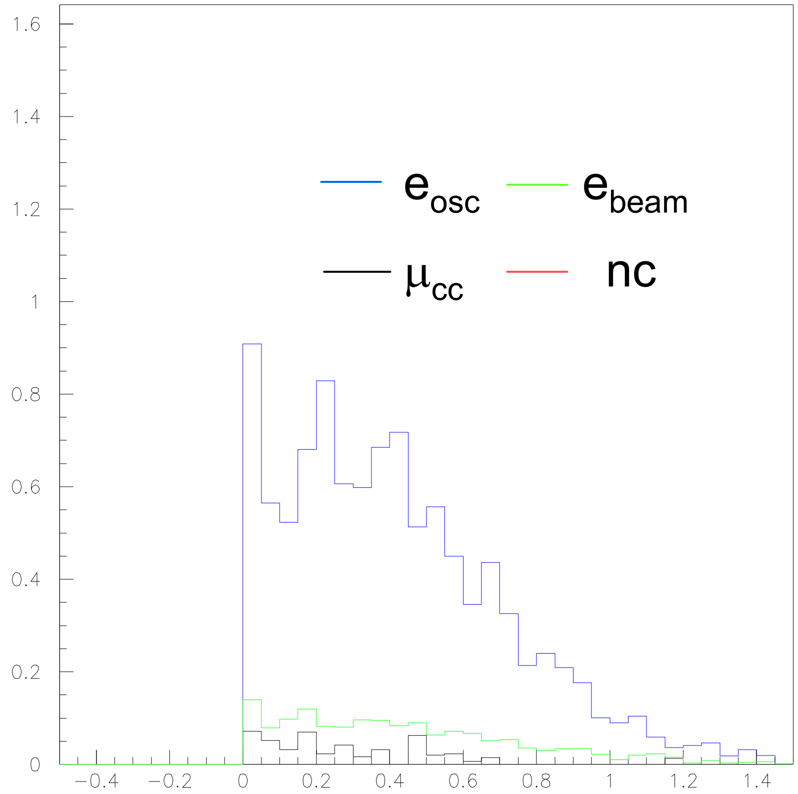


Number of μ decay hits

- Reject events where the prime track has a late hit less than 12cm in z from the track end

π^0 rejection

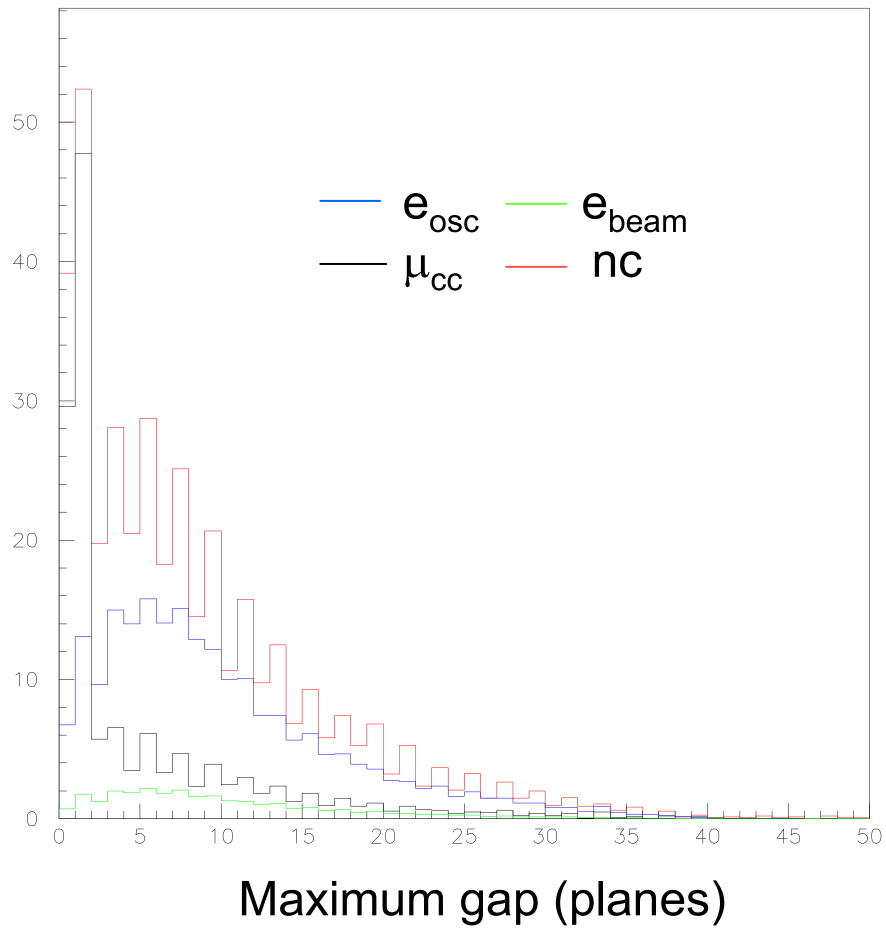
- The Hough track finding has been extended to find extra tracks after the prime track (most hits)
  - By scanning the second track is quite often a reasonable track
  - The third and subsequent tracks are mostly rubbish
  - Limit analysis to three tracks
- If the Hough analysis finds more than one track and the prime track passes the electron cuts, combine the extra tracks to form a π^0 (assuming both are γ)
  - Evidence for π^0 in nc events
  - Cut events with π^0 mass^2<0.1



π^0 mass^2 (GeV/c^2)^2

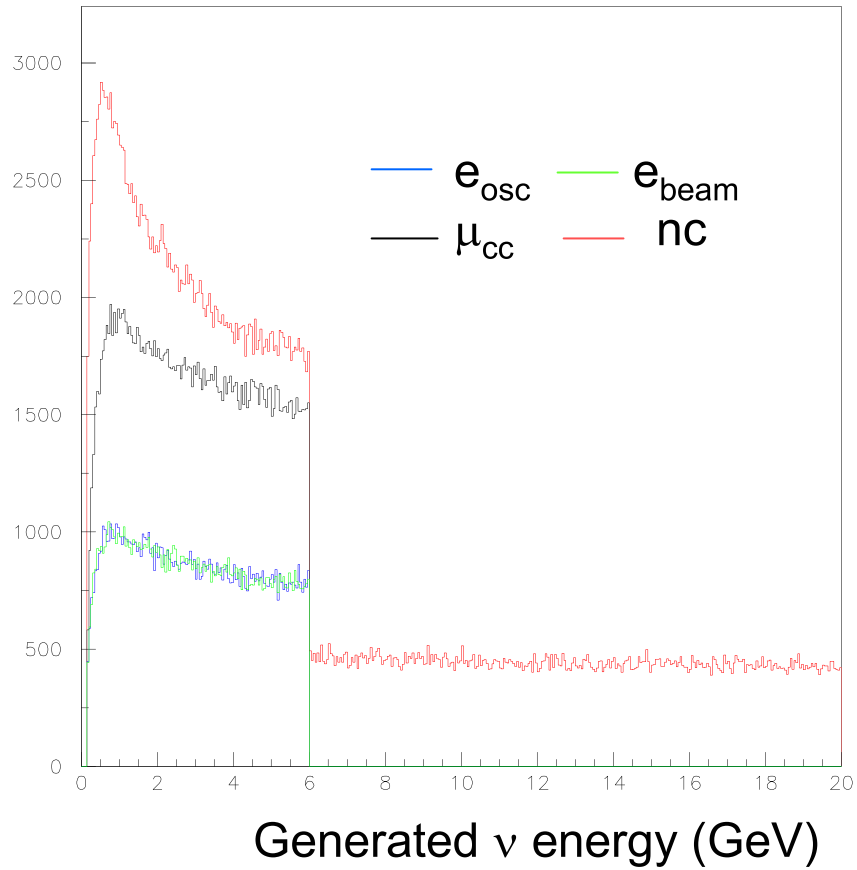
Improved gap recognition

- Electrons are characterised by the presence of gaps in the track
  - Previously this was not being calculated optimally for the TA detector
  - Find the maximum plane gap within the prime track
  - Reject events where the maximum gap is ≤1

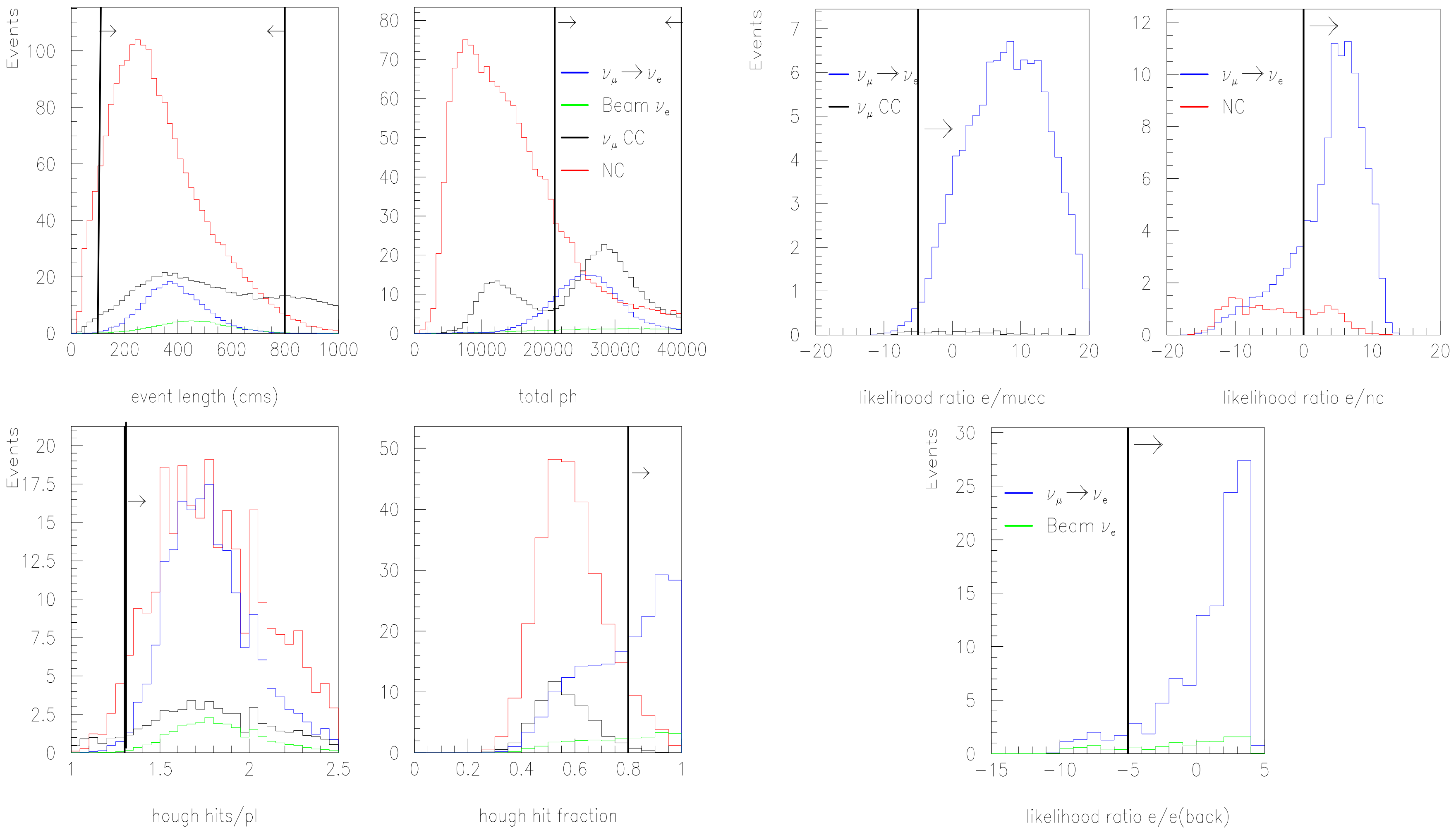


Flat energy generation

- Due to a misunderstanding I had assumed that the generated events were flat in energy. This was not so, they were generated with a 1/E distribution which gave a flat energy distribution at high energies but not at low.
  - Sum the generated events and weight each energy bin to produce a flat distribution.
  - In my analysis flattening the distribution reduced the FOM by ~0.3



Other cuts



Events
event length (cms)
total ph
$\nu_\mu \to \nu_e$
Beam ν_e
ν_μ CC
NC
likelihood ratio e/mucc
likelihood ratio e/nc
hough hits/pl
hough hit fraction
likelihood ratio e/e(back)

Results

test passed	μ cc	nc	e_{back}	e_{osc}	back	fom
generated events	193626.00	371058.00	100000.00	100000.00		
beam weighted	7481.66	3441.16	98.15			
beam weighted + osc	1278.04	3441.16	98.15	310.19	4817.35	4.47
reconstructed events	1251.88	2427.40	94.51	299.53	3773.79	4.88
containment volume	880.56	2037.75	75.58	245.53	2993.90	4.49
event length	539.43	1879.90	74.34	244.54	2493.66	4.90
total pulse height	328.79	407.98	29.03	217.64	765.79	7.86
μ decay hits	184.58	393.40	28.70	215.63	606.68	8.75
hough track gap	65.43	298.94	26.22	195.96	390.59	9.92
hough hits/plane	58.44	288.13	26.05	194.36	372.62	10.07
hough track hit fraction	1.31	21.84	11.90	99.64	35.05	16.83
hough beam angle	1.31	21.84	11.90	99.64	35.05	16.83
pizero cut	1.21	20.36	11.69	98.27	33.27	17.04
likelihood cut	0.48	5.82	6.59	73.31	12.90	20.41
error	0.10	0.36	0.09	1.14	0.39	0.44
raw events remaining	28.00	826.00	5178.00	5154.00		

Results

- My current best results from a test sample are;
  - FOM=20.4±0.5
  - 73.3 signal, 12.9 background, signal efficiency 24%
  - Training sample gave a FOM of 21.6
- Very disappointing. My previous FOM before all the "improvements" was ~20.3
- The new cuts are particularly strong on the μ cc background. This is now essentially zero.
- Nothing much seems to improve the nc background
- Reinforces my conclusion from previous optimizations and from my scan analysis that the FOM is essentially saturated. There are statistical fluctuations of ~0.5-1.0 but it is difficult to make a systematic improvement.

Comparison with Stan

- Stan sent Dan Hennessy what we thought was his code but we find now is that of his student from last summer. Dan has now got it working and we have tried to compare the Minnesota and Stanford analyses.

- Almost everything is different…. maybe surprising we are as close as we are

- With the code we have and running on the same generated data sample the Stanford best FOM is 21.6 for the test and 22.0 for the training sample (c.f. 20.4, 21.6 for my analysis and ~24 which Stan reported at the October meeting)

- Stan has a less restrictive fiducial region, using his definition increases my FOM by ~0.3

- The test and training samples are defined differently, there are statistical differences ~0.5

- I was prepared to declare them the same but Stan says he has now updated his analysis and gets a better FOM

Cell size optimisation

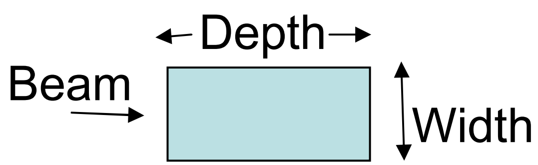
- Leon has generated detectors with different cell sizes.
  - Widths (perpendicular to beam) of 3.8, 5.2 and 7.9 cm
  - Depths (along the beam) of 4.5, 6.0 and 9.0 cm
- Two hypotheses for the readout light level
  1) Keep the same number of pe collected/cm of track
  2) Renormalise the light level to 35 pe at the far end of the cell
- The first gives the most direct comparison of the selection and pattern recognition, many tests are to first order unchanged under different cell configurations. All of the generated conditions compared in these conditions
- The second is what we would probably do to save money in building the detector. The 9.0cm depths compared this way.

Cell size results

- The FOM was reoptimised quickly for each condition, mostly the parameters were similar except for the pulse height cuts for the low light level cases.
- Compare the best FOMs for the training sample
  - Avoids extra statistical fluctuations in the test sample
  - Statistical error ~0.5, systematic error due to optimisation ~0.2

	High light Depth			Low light
Width	4.5cm	6.0cm	9.0cm	9.0cm
3.8cm	21.6 (21.6)	21.1 (22.6)	20.0	20.0
5.2cm	20.9 (20.5)	21.6 (21.1)		
7.9cm	21.0		20.5	20.5

- ( ) Dan's numbers from Stan's "1D ML" test sample



Cell size results

- Expected effects are seen.
  - Fewer hits/plane in the wider cells.
  - Smaller gaps in the longer cells.
  - Total pulse height slightly larger in the bigger cells, less inert material.
  - Half the total pulse height in the low light sample
- Very little overall difference in the FOM.
- Could be worth scanning a sample of the larger cell sizes to see if one can tell by eye whether the pattern recognition would be significantly worse
- Cell size will probably be set by mechanics?
- Save money on the cell size and put it into more mass.

Off-axis position optimisation

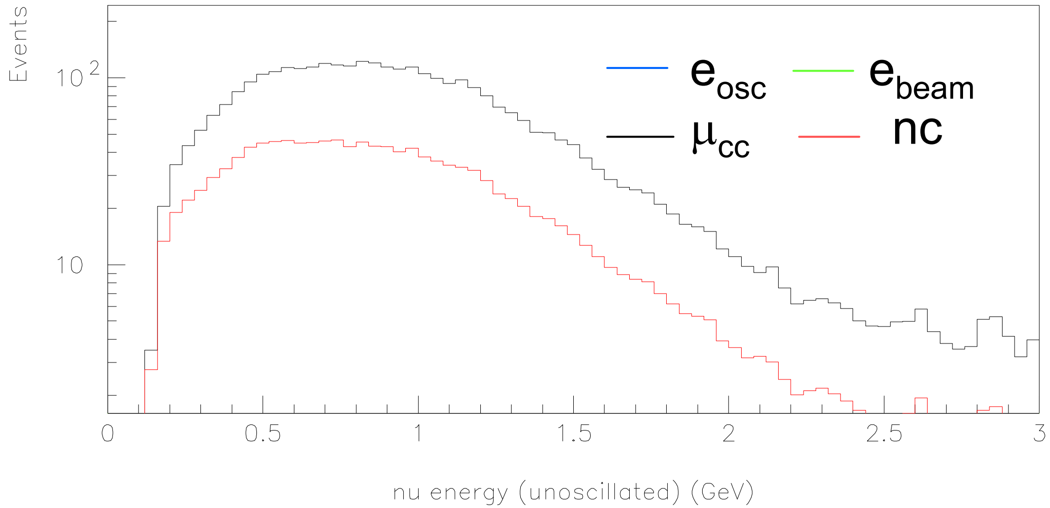
- Need to repeat the optimisation as a function of offaxis position as was done for the wood detector.
- Include the $\overline{\upsilon}$ background in the beam and do the opposite sign beam
  - Just started, another ~1-2 weeks
  - Inclusion of $\overline{\upsilon}$ background reduces the FOM by ~1

8 Gev beam

- Doug Michael has proposed a using the proposed Fermilab proton driver to power a new beam complex consisting of off-axis 120GeV beams plus a low energy beam similar to the MiniBoone beam pointing at the Homestake mine (1290 km).
- Either a 125kton liquid argon or 0.5Mton water cherenkov detector would be the detectors.
- The objective is to combine the advantages of off-axis and on-axis beams to cover the first and second oscillation maxima in a similar (but possibly better) way than the Brookhaven proposal.
- What could an upgraded 8GeV Miniboone beam do, pointed at Noνa, to cover the second maxima in the same detector?
- Assume 10^{23} protons on target (5 year run?) into the 25kton TASD detector at 810 km from Fermilab

Beam spectra

Unoscillated ν_μ and nc truth energy spectra. Intrinsic ν_e spectrum taken as 0.005*ν_μ spectrum



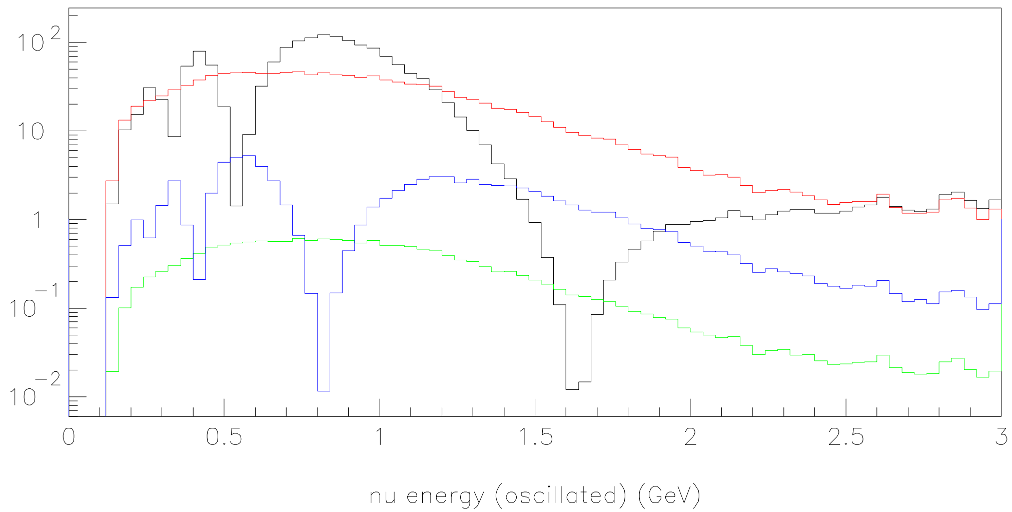
Oscillated spectrum

Δm^2=0.0025 eV^2

$\sin^2 2\theta_{23}$=1.0

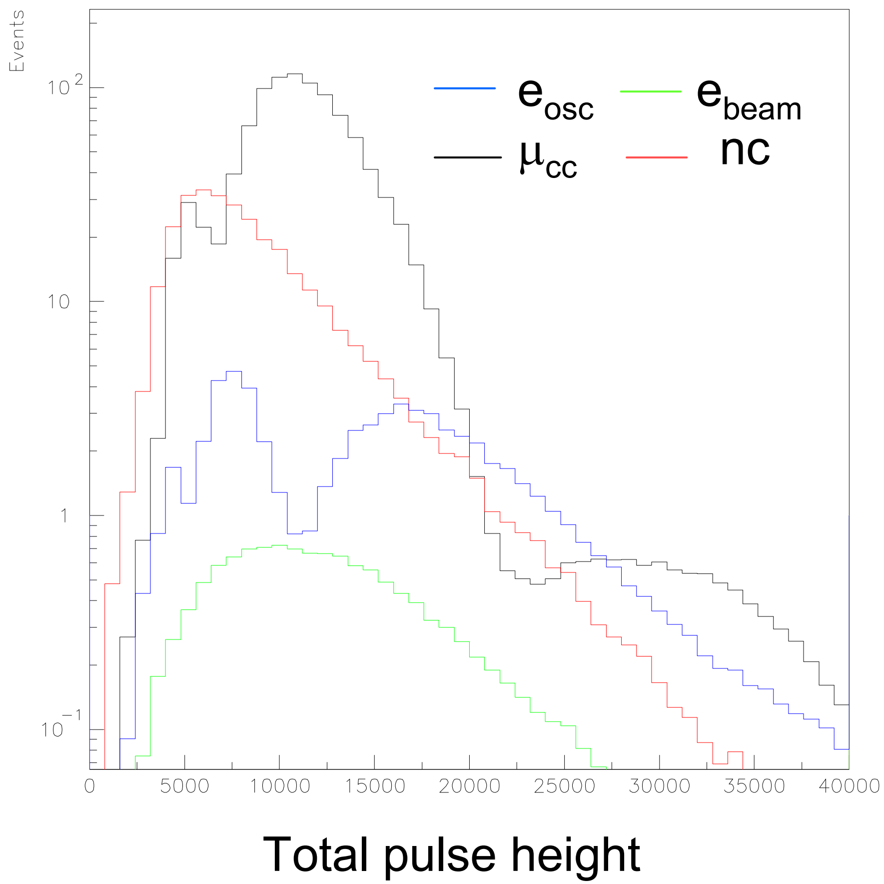
$\sin^2 2\theta_{13}$=0.1

No matter or CP effects



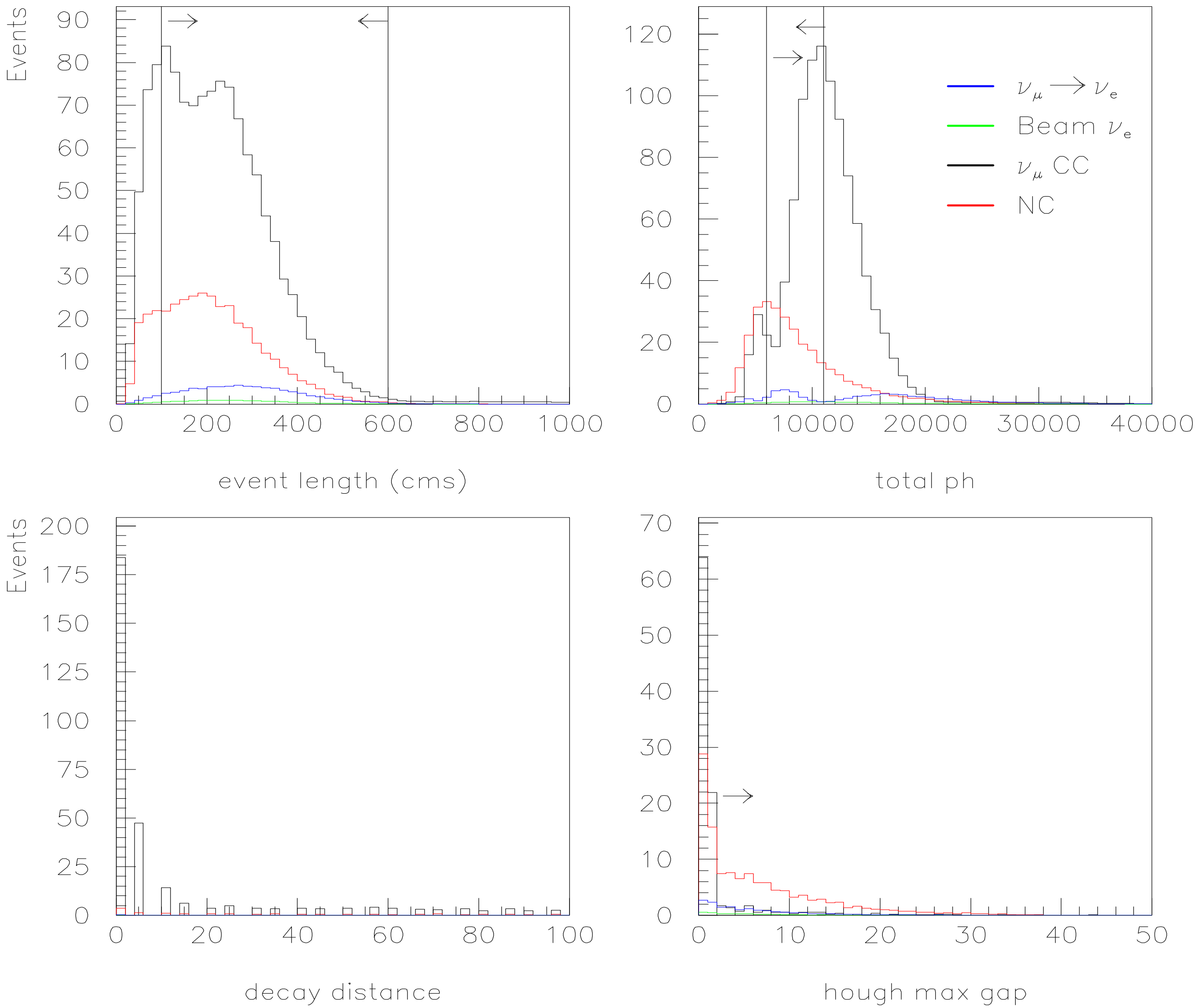
8 Gev Beam

- 2^{nd} maximum occurs at ~600MeV
- Energy resolution in TASD is very good, the 2^{nd} maximum is well separated from the 1^{st}.
- Select events in the second maximum peak
- Apply the same analysis as described earlier
- Differences at low energy;
  - Electrons produced at wide angles
  - Large fraction of quasi-elastics
  - Need the μ decay flag to reduce μ cc background



Analysis

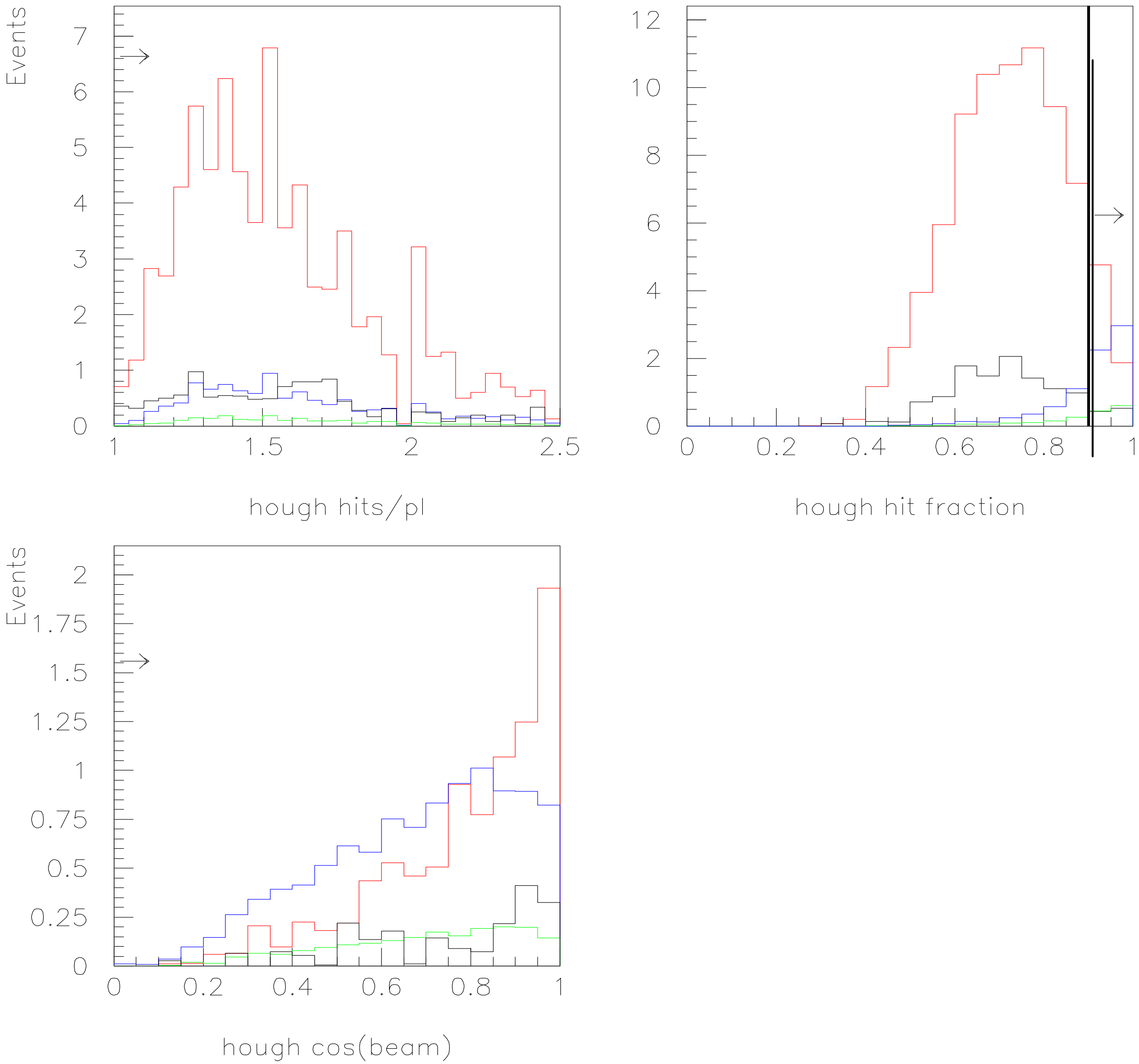
- Reject event if
  - 100cm<event length <800cm
  - 6000< ph <11000
  - Any late decay hit
  - Maximum plane gap ≤1



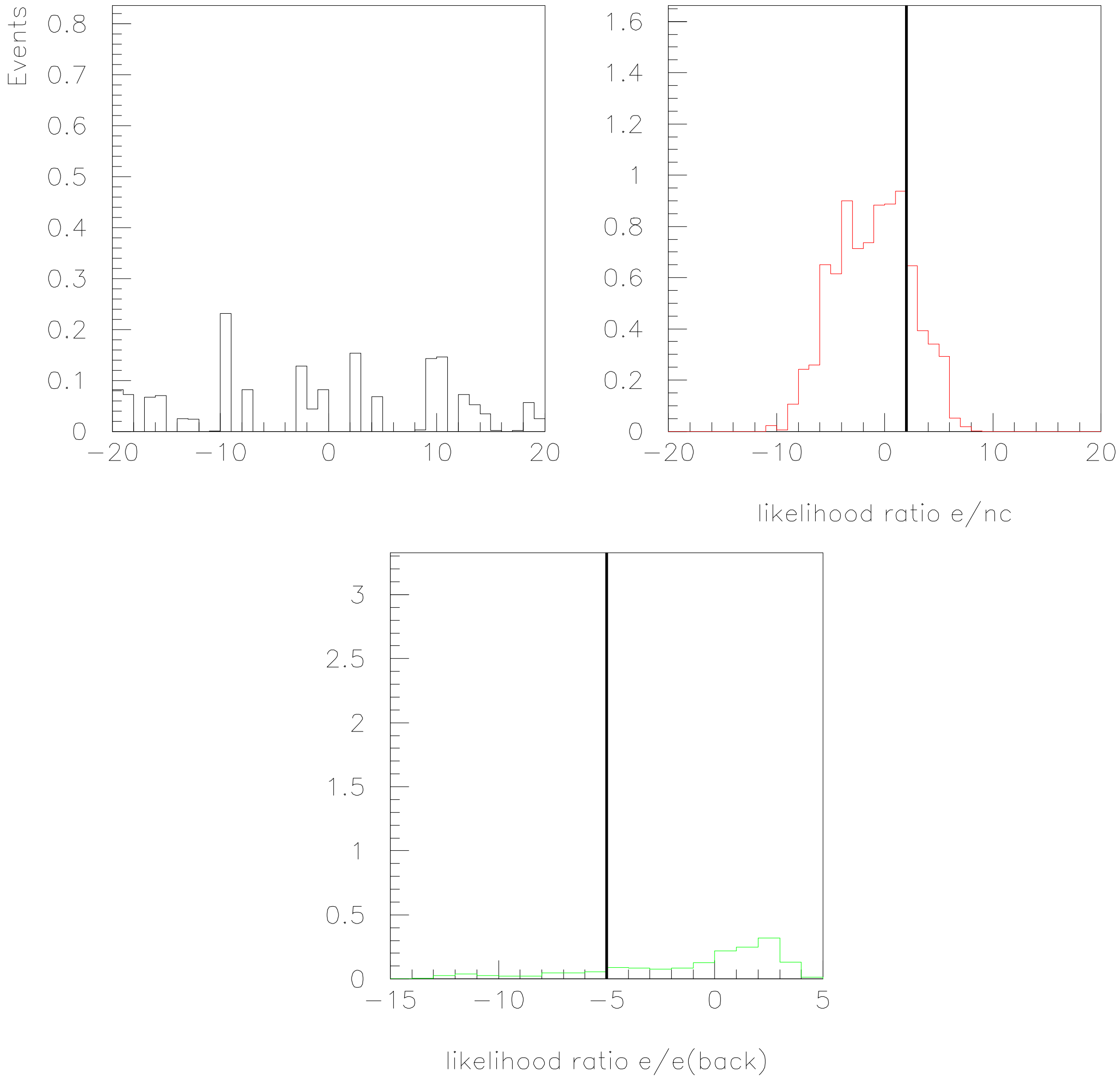
Analysis

❖ fraction of hits in track > 0.9

❖Note: no cut on average number of hits/plane or the beam angle



Analysis



Results

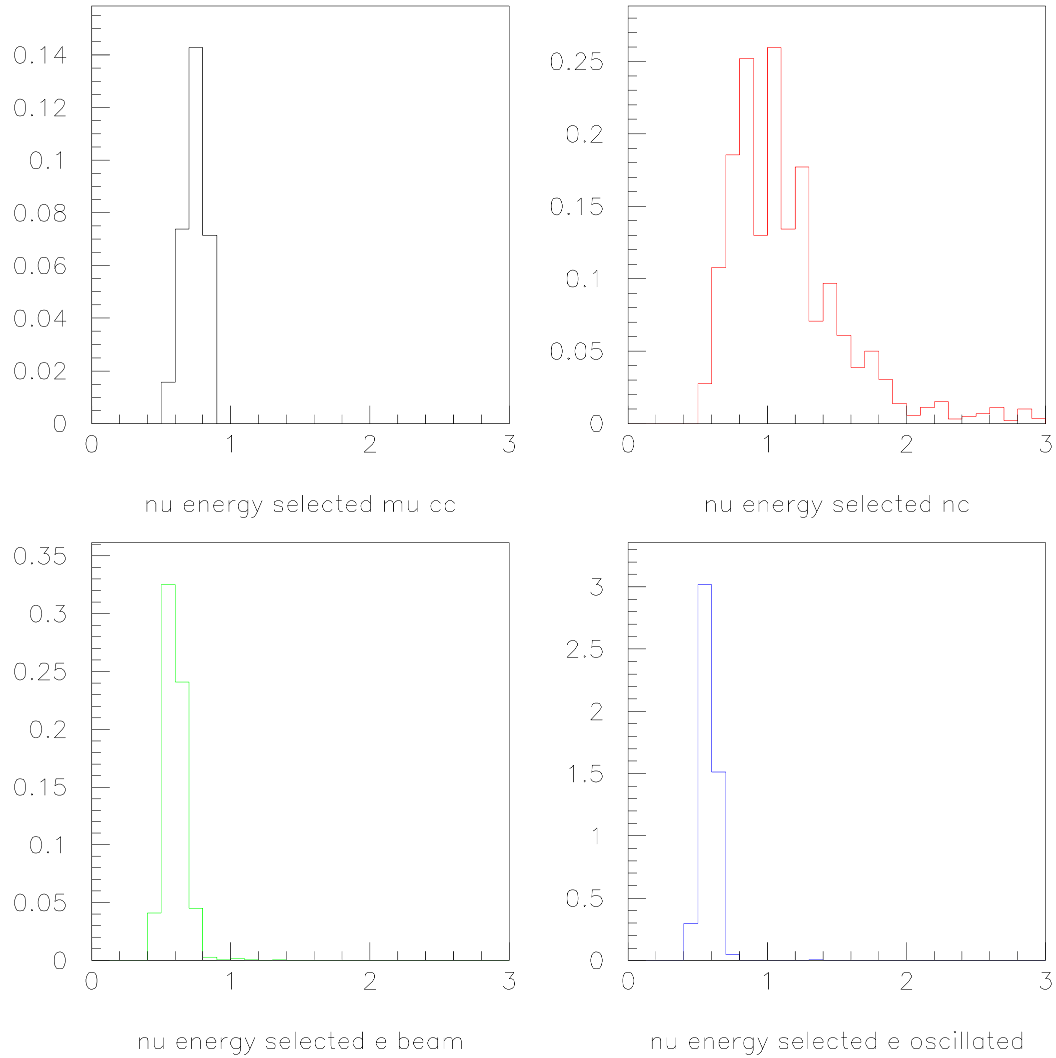
test passed	μ cc	nc	e_{beam}	e_{osc}	background	fom
generated events	98240.00	99236.00	51623.00	51589.00		
beam weighted	3323.95	1273.33	16.62			
beam osc	1568.08	1273.33	16.62	87.76	2858.04	1.64
reconstructed events	402.56	402.04	15.39	81.48	1819.99	1.91
Containment volume	1224.27	370.21	13.63	71.17	1608.10	1.77
event length	990.48	305.37	12.52	65.46	1308.38	1.81
total ph	425.65	147.91	4.11	18.19	577.67	0.76
# mu decay hits	96.53	124.46	3.36	16.23	224.35	1.08
maximum gap	12.63	80.42	2.38	11.32	95.42	1.16
hough hit/plane	12.63	80.42	2.38	11.32	95.42	1.16
hough fraction	1.87	8.71	1.68	8.85	12.26	2.53
hough beam angle	1.87	8.71	1.68	8.85	12.26	2.53
pizero cut	1.87	8.70	1.67	8.84	12.25	2.53
likelihood	0.30	1.71	0.66	4.88	2.67	2.99
error	0.14	0.19	0.02	0.17	0.23	0.17
raw events	9.00	147.00	892.00	922.00		

Energy acceptance

❖ Truth energy of accepted events

e_{osc} e_{beam}

μ_{cc} nc



Is it any good?

- Find 4.9 events with 2.7 background. Not very interesting…..
- BUT the beam is maybe not optimum
  - More beam? Doug's scheme had 2MW from the driver on the 8Gev beam and 2 MW on the NuMI beam. Everything on the 8 Gev beam? X2?
  - Better beam? An off-axis 8Gev beam could have more events at 600 MeV (x3-4?) and less high energy nc events, less background.
  - Better intrinsic ν_e simulation, less background
  - 30-40 events with less than 10 background?
- Detector is maybe not optimum
  - Noνa TASD acceptance ~30%, a detector with 90% acceptance would have x3 events (~100 events). 25kton liquid argon?
  - OR build another 25 kton of TASD (60-80 events)